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STUDIES IN . . .

# Hydrology of Agricultural Watersheds

Coshocton, Ohio

U.S. Department of Agriculture  
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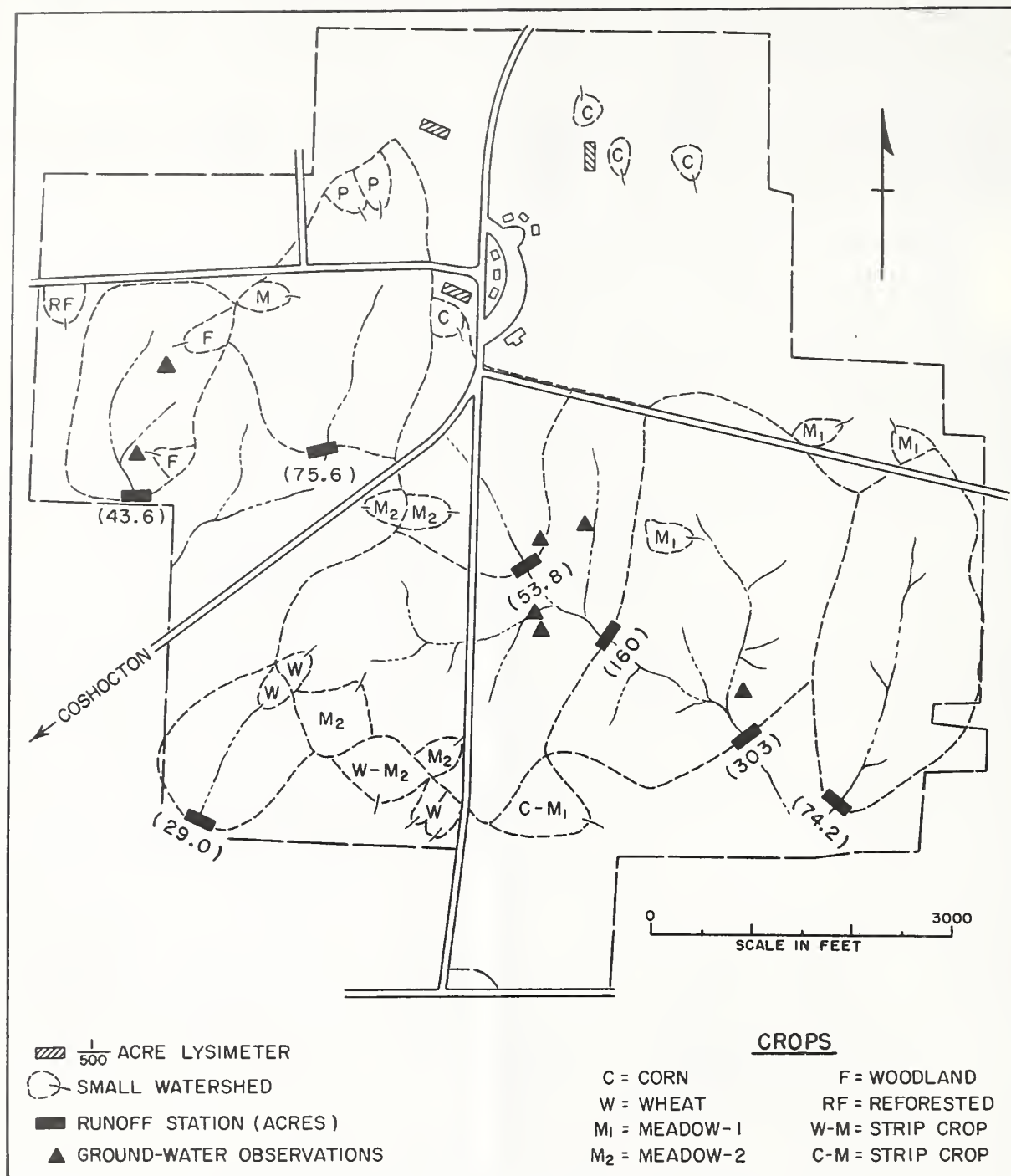
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U. S. Department of Agriculture  
AND THE OHIO SOIL CONSERVATION COMMITTEE  
in Cooperation with  
OHIO AGRICULTURAL EXPERIMENT STATION  
Wooster, Ohio



MAP OF THE RESEARCH STATION LAND

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 January 1962

# Studies in Hydrology of Agricultural Watersheds

## FOREWORD

The Coshocton Station serves the farmers, watershed planners, and engineers of the Nation. Too much water or too little water, along with topsoil losses by erosion and waste of fertilizer in runoff water are problems common to farms in the humid section of the United States.

Many years ago, large areas of dense woods and tall grass in this region were cleared and broken for cultivation. Removing this natural vegetation from the land surface caused soil erosion and water waste to increase. Advancing civilization brought land operations that increased flood damage and destroyed good water supply systems through silting of reservoirs and the clogging of river channels with debris washed from the land. Waste of soil and water diminished crop production. It was apparent that something must be done. The march of civilization called for flood prevention, good water supplies, clean rivers, and high food production. There was a need to develop facts on what should be done and to evaluate the effect of changes on whole watersheds.

In 1935 the United States Department of Agriculture Soil Conservation Service selected an area 10 miles northeast of Coshocton on State Route #621 and located a research station designed to study water, land use, crops, and erosion on individual farm fields and on entire watersheds. In January 1954, the Station was transferred to the Agricultural Research Service of the Department.

This site was chosen because it typified much of the agricultural land in the unglaciated Allegheny Plateau. This covers part of southeastern Ohio, western Pennsylvania, western West Virginia and a portion of eastern Kentucky.

Here, research workers are studying the influence of various agricultural practices on erosion losses and on various elements of the hydrologic cycle. The more promising agricultural practices are applied on station land for evaluation. Some of the highlights of this research in agricultural hydrology are presented on the following pages.

Newly employed technicians of the U.S. Soil Conservation Service in 22 states from Missouri and Minnesota on the west to Virginia and Maine on the east, are assigned in small groups to the Coshocton Station for instruction and training in the latest methods of

conservation farming. Specialists in the major fields of agriculture help train these men in up-to-date farm practices for attaining the goal of maximum soil and water conservation in the shortest possible time.

Visitors come to this station from all parts of the earth, seeking knowledge of research in soil and water conservation. Farm groups, students, clubs and many others from Ohio and from almost all of the other states have traveled here to view the research work.

## FACTS ABOUT THE STATION

Of the 1,047 acres of the Coshocton station land, about two-thirds was purchased by the United States Government and one-third was purchased by Coshocton County officials and leased to the federal government. The United States Department of Agriculture and the Ohio Agricultural Experiment Station cooperate in the planning and operation of experiments designed to discover new and better ways of using the sloping land in this region for a more permanent agriculture, prevention of floods, and more efficient use of water.

The station land is comprised of about 470 acres of cropland, 270 acres of permanent grassland, and 307 acres of woodland. The predominant soil, Muskingum silt loam, is a well-drained residual soil of shale or sandstone origin. It is found on the steeper lands. The soil on the gently sloping lands, Keene silt loam, is slowly permeable and of shale origin.

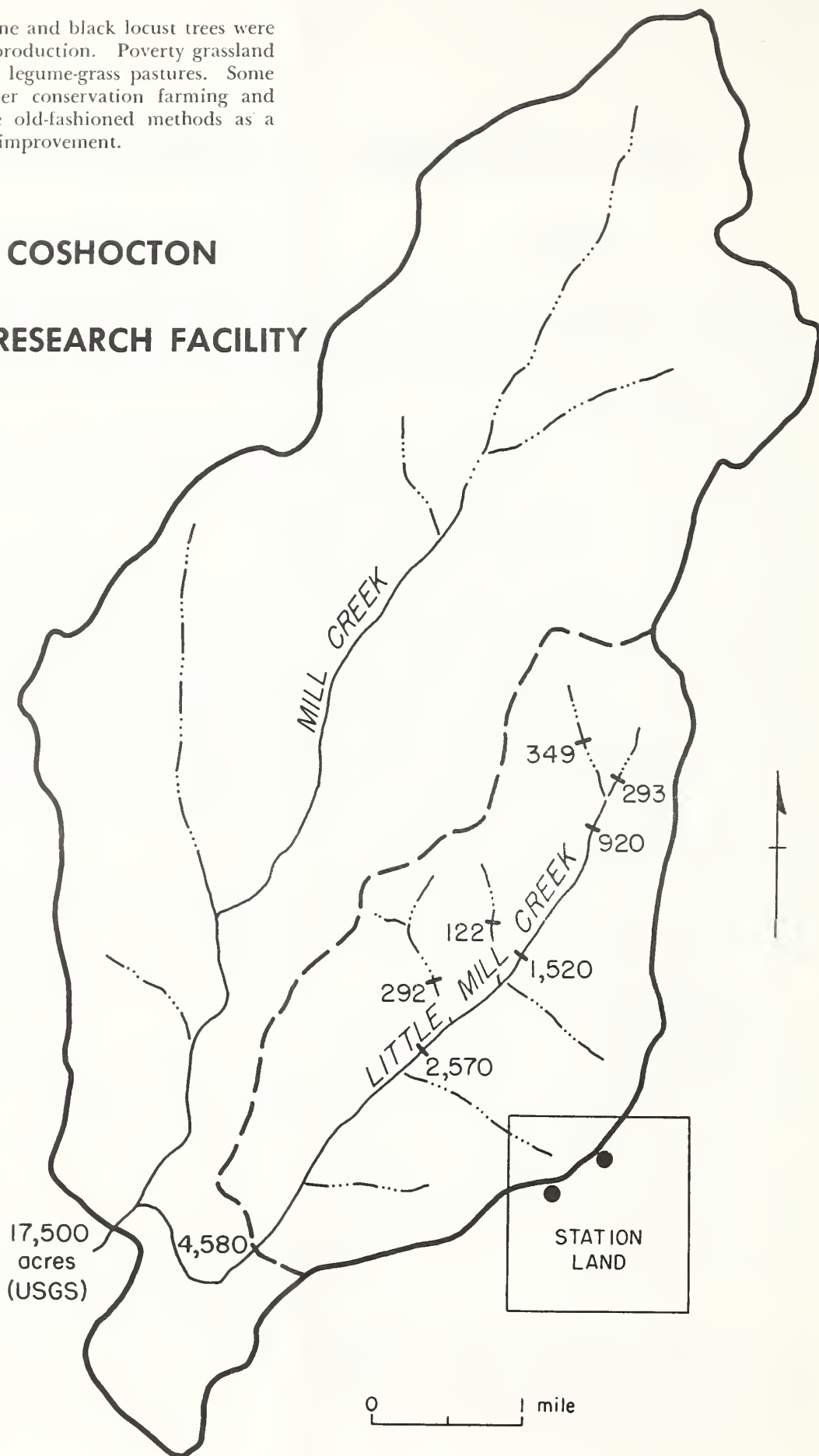
Several factors make resource conservation imperative in this area. First, the depth of topsoil is shallow, thus making conservation of soil of prime importance. Secondly, the incentive for the most efficient production of crops on each acre of land, along with occasional periods of low rainfall, make water conservation vital to agriculture in this area. Thirdly, frequent and costly flood and sediment damages make it desirable to study the development of floods from agricultural lands to determine and evaluate methods of flood damage reduction. Data on the effect of land management on yield of surface and underground water become more valuable as demands for usable water increase.

The program of putting each acre to its best use began with planting the steep, badly eroded land to

trees. Many acres of pine and black locust trees were planted for fence post production. Poverty grassland areas were renovated to legume-grass pastures. Some fields were placed under conservation farming and some were kept in the old-fashioned methods as a check on the value of improvement.

## MAP OF THE COSHOCTON

### WATERSHED RESEARCH FACILITY





A number of rainfall and runoff gages are located on privately owned land adjacent to the Station. Here the gaged watersheds range from 122 to 4,580 acres. Data from the U.S. Geological Survey Station further downstream are available to extend the research results up to an area of 17,500 acres. Land use in the Mill Creek and the Little Mill Creek Watersheds, adjacent to the station land, is typical of the problem area. It consists of 30 percent woodland, 27 percent pasture, 21 percent rotation meadow, 18 percent cultivated crops (mostly corn and wheat), and 4 percent miscellaneous. The cropping sequence is corn, wheat, meadow.

Much of the detailed research program is carried out on this station land.

Small watersheds of one to eight acres in area provide a means of evaluating *units* of soil, cover, and land treatment. Woods, permanent meadow, pasture, and rotation crops (corn, wheat, and two years of meadow) are represented by these natural watersheds. There is one untreated pasture and one treated (medium high fertility and deep-rooted grass and legume). Rotation crops are managed for either moderately low-level production with straight-row tillage or for moderately high-level production with contour tillage. Also, different systems of tillage (mulch or minimum) are tested on a separate series of watersheds in their corn years. The 1961 crops are shown on the map.

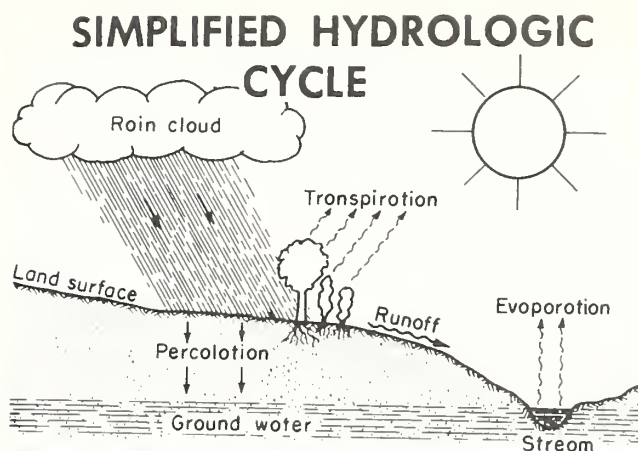
Mixed cover and soils are found on cropped watersheds from 29 to 303 acres in size. Those of 74.2 and 303 acres have, from the start of the research program, been retained in the moderately low level of production with straight-row tillage. In 1944, improved practices with contour strip cropping were introduced on those of 29 and 75.6 acres.

The eastern one-third of the 43.6-acre watershed has been in mixed hardwoods for many years. The western two-thirds had been cleared, farmed, eroded and abandoned to poverty grass. In 1939 pine trees were planted in this area.

### THE HYDROLOGIC CYCLE

The hydrologic, or water, cycle has no beginning or ending, but we can think of it as beginning with moisture in the atmosphere. Water is evaporated into the atmosphere from land and water surfaces, is lifted, and eventually condenses and returns to the earth's surface as precipitation. Precipitation that falls on the land as rain, hail, dew, snow, or sleet is of particular concern to man and agriculture.

All phases of this hydrologic cycle are studied at Coshocton. Gages for measuring rainfall, runoff, and soil erosion are seen at many places throughout the experiment station — on cropland, pastures, meadows, and woods. After each rainstorm, the chart re-

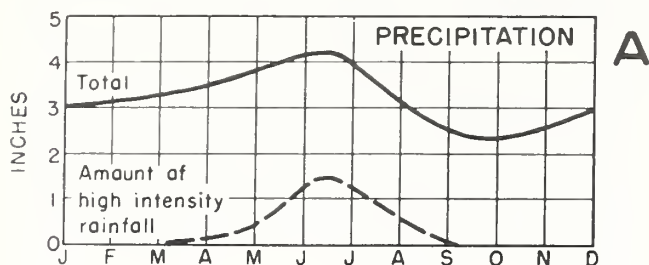


The lysimeter: Above ground, the 1/500 acre plot and below ground, the weighing mechanism. A delicate scale weighs the 65-ton block of earth every few minutes to record rainfall additions and evaporation losses. Runoff and percolation are measured by other instruments. Thus the effect that various crops have on all elements of the hydrologic cycle are evaluated.

cords from each gage are removed and used in compiling data on precipitation, runoff, and sediment production. Additional observations show how much water is absorbed by the soil, how much of this is used by crops, and how much seeps to the ground water reservoir.

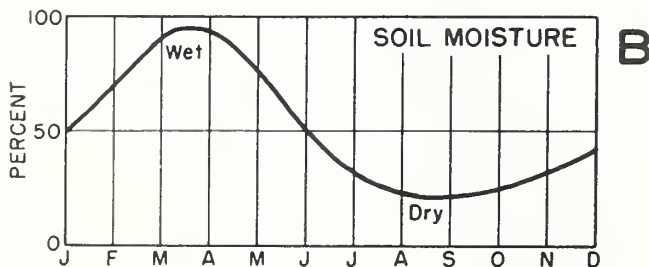
The 1/500-acre lysimeters, each having 8 feet of undisturbed soil, measure rainfall, runoff, evaporation, percolation, and water use by crops. Of the eleven lysimeters, three are weighed at 10-minute intervals. On a gross weight of about 65 tons, these scales have an accuracy of 5 pounds.

## HYDROLOGIC RELATIONSHIPS

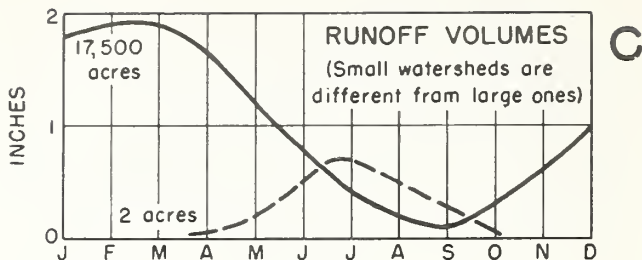


- A. Normal precipitation pattern shows fairly even distribution of monthly totals throughout the year. May, June, and July values are each over four inches — ideal for agriculture.

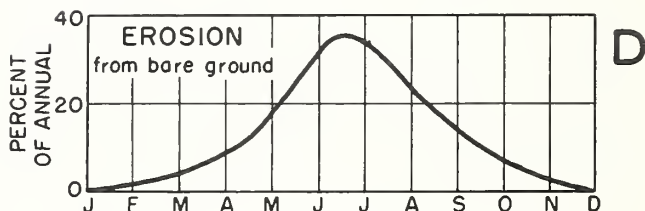
Amount of rain falling at high intensities is greatest in these same months. At times it is difficult for the soil to absorb much of this storm rainfall — especially when in row crops.



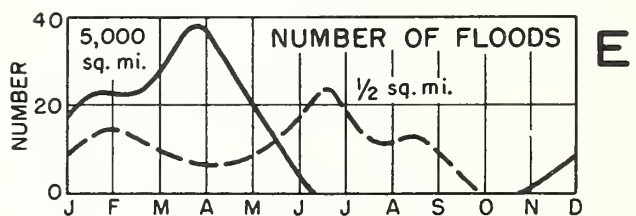
- B. Soil moisture depletes rapidly during the growing season, May - October. For much of this season, the volume of soil pores available for storm water absorption is normally large. With lower temperatures and dormant vegetation in the fall and winter, crop use of water is smaller and recharge to soil moisture occurs — even though rainfall amounts are normally small. By March-April, the soil profile often approaches saturation, and the capacity of the soil to absorb storm rainfall is practically negligible.



- C. Runoff volumes from small watersheds are greatest in the May-September period. Although the soil is fairly dry and water storage capacity is large, rainfall rates are so high that runoff occurs. These rainstorms usually cover only small areas and do not cause much runoff on the large watersheds. Runoff volumes from the larger watersheds are greatest in the wet season. Rainfall rates are usually low, storms are of long duration and cover large areas, and soil water storage capacity becomes very small.

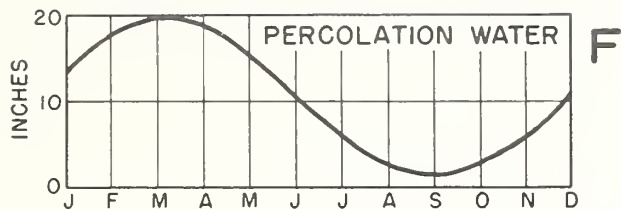


- D. Erosion from bare land occurs mostly in the growing season when rainfall intensities are high and rain drops are larger, with exceedingly high values of kinetic energy.

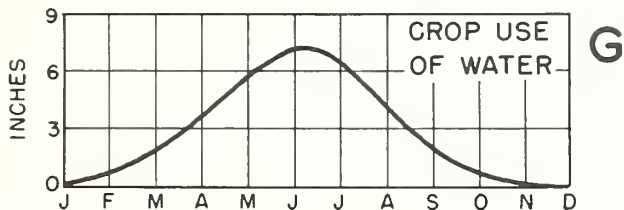


- E. The greatest number of maximum annual flood events for the small watersheds occur in the growing season. Local, high-intensity storms are the cause. For the larger watersheds, the major floods occur in the late winter and early spring season. Large area, long duration storms, even though of low intensity, on wet soils combine to cause these floods.





F. Percolation, which is essentially recharge to ground water, is greatest during the February-April period. Naturally this is also the season of greatest rate of rise in ground water levels.

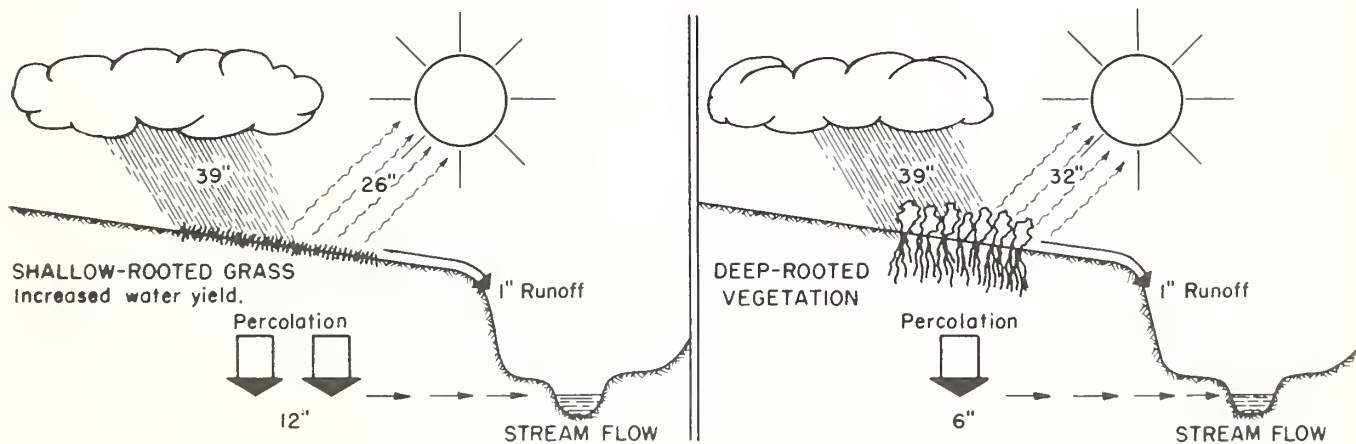


G. Crop use of water is greatest in the warm season. It diminishes in the hot months of August and September because of the lack of soil moisture in the root zone.

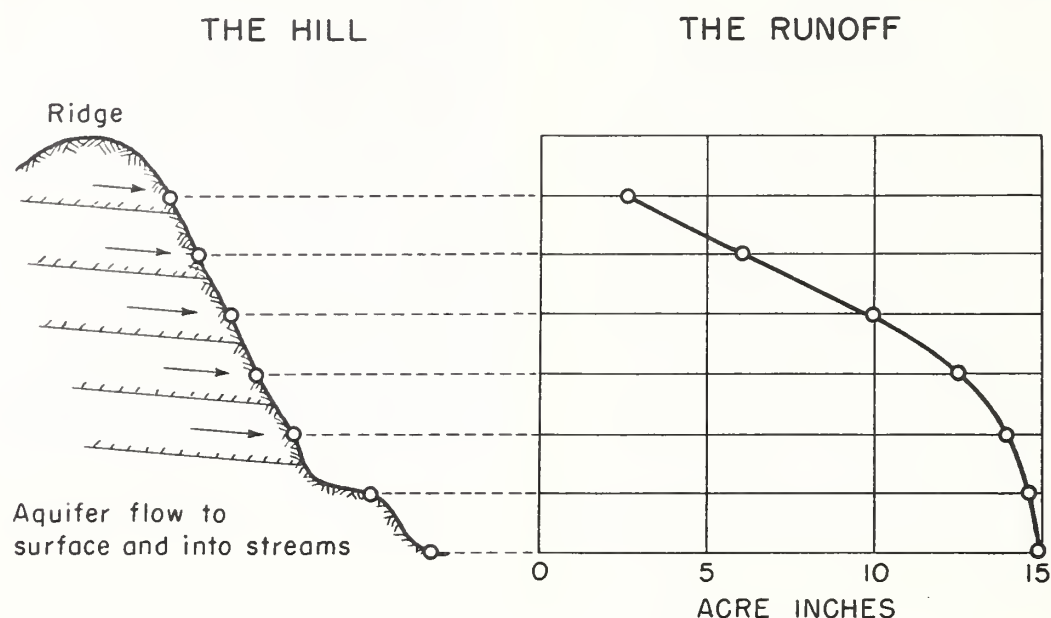


Evaporation pans help measure crop use of water

## LYSIMETERS MEASURE LAND TREATMENTS EFFECT ON WATER USE AND PERCOLATION



# GEOLOGIC INFLUENCES ON WATERSHED HYDROLOGY



○ Denotes location of runoff measuring station on a hillside and also volume of annual runoff at each site.

1. The watersheds are underlain by a repetitious sequence of sandstone, coal and clay formations.
2. The more permeable formations, limestone, coal and sandstone, are individual aquifers with the interbedded clay horizons restricting vertical percolation. Subsurface flow contributes to stream-flow as the channel incises each underlying aquifer.

3. The larger the watershed, the deeper is the channel incision into the geologic column. Ground-water flow in the channel increases with drainage area and depth of incision up to 1000 acres.
4. Studies are being made to determine the pattern of subsurface flow, the rate and volume of water movement and factors affecting aquifer stream-flow relationships.

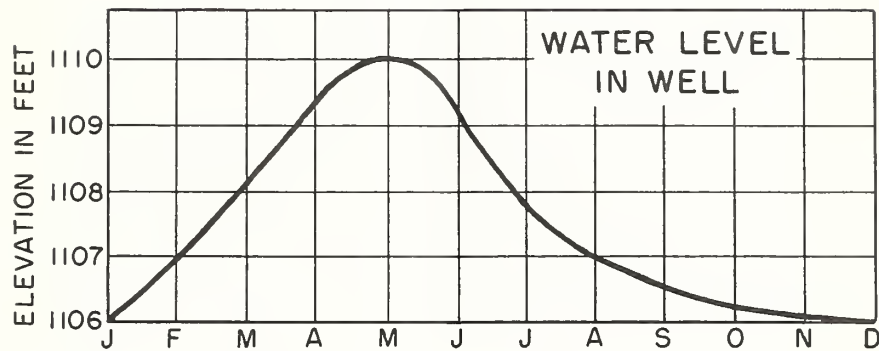
Dense vegetative land cover on well-drained soil maintains porous surface for rapid water absorption. Runoff volumes are small.

Shallow-rooted crops in dry seasons use less water than deep-rooted crops, therefore, percolation, or recharge to ground-water, is greater. In wet seasons, there is little difference. Shallow-rooted grass increases water yield to stream flow.

Ground water levels generally increase from January through April. Soil moisture recharge which begins in October and reaches a maximum by February-March precedes the highest rate of water table increase.

In some years, soil-moisture deficits are so great at the end of summer that the fall-winter precipitation absorbed into the soil is not enough to overcome this deficit and have enough left over to raise the ground water levels materially. These are times

## SUBSURFACE WATER STUDIES



Drilling rig used to obtain soil samples for study of subsurface earth layers and groundwater levels.

Well water level recorder



of water shortage in wells and in streams fed by ground water. Watershed land-management programs at the Coshocton Station are having some effect on soil-moisture storage, ground water recharge, and stream flow.

Geologic explorations serve to determine the contributions of ground water to stream flow and to help evaluate the effect of watershed management programs on these water resources.

The soils laboratory is equipped to study the physical characteristics of the soil and how they are changed by improved land management practices. Samples of runoff water are analyzed to determine the erosion from farm fields under different management practices. Soil samples are tested for pore size distribution and water retention and transmission.

Soil-moisture studies are made in the field to locate and evaluate pore space available for storm rainfall absorption and the moisture extraction pattern of various crops on different soils.

Water and soil are wasted as storage space in soil pores goes unused. This is illustrated by data from the storm of July 28, 1950, on a 3-acre watershed.

Normal improved - practice farming, 7-inch topsoil:

Storage space available before storm	2.79 inches
Storm rainfall	1.11 inches
Runoff from cornfield	.47 inch
Water absorbed by the soil	.64 inch
Storage space used by the soil	.64 inch
Storage space unused	2.15 inches
Erosion:	2 tons per acre.

Studies of the soil at the Station show that water can be absorbed by medium-moist soil in cornfield at different rates such as:

Crusted surface	0.70 inch	per hour
Top soil, uncrusted	6.00 inches	per hour
Subsoil	.25 inch	per hour

Leaching of plant food beyond the root depth is measured in the percolation water. On the average, records from these lysimeters show that 4 pounds of nitrate, no phosphorous, 12 to 16 pounds of potash, and 25 pounds of calcium are leached annually from an acre of cropland. Conservation practices that call for increased application of mineral fertilizer and more intensive cropping have not resulted in increased leaching of nitrogen and potash.

## SOIL STUDIES IN THE LABORATORY



Erosion and permeability studies in the soil laboratory



## SOIL STUDIES IN THE FIELD



**Field measurements of soil moisture by the neutron method**

Mulches and minimum tillage result in less crusting and greater water-absorption capacities than fields having normal plowing and fitting operations. The following data typify the effectiveness of these land treatment practices on watersheds in the 3-acre category:

Storm of July 27, 1956		Minimum Tillage
Management	Runoff Inches	Erosion Tons/acre
<i>Conventional tillage</i>		
Untreated	0.70	1.71
Treated	.41	.30
<i>Minimum tillage</i>		
Treated	.10	.01

**Note:** "Treated" denotes farming practices recommended in the Soil Conservation District program — contouring, liming, fertilizing adequately, deep-rooted legumes. Corn production level for untreated = 50 bu. and for treated = 100 bu. per acre.

The effect of changing the vegetation on two-thirds of the 43.6-acre watershed has been quite noticeable on its streamflow. In 1939 one-third of the area was in mixed hardwoods, two-thirds in shallow-rooted poverty grass. Pine trees were planted on this badly eroded land and their roots penetrated deep into the soil, withdrawing water throughout the season. In 1957, 19 years after planting, the annual streamflow was 5.3 inches less than it would have been if it had remained in the original condition. Reduction for the dormant season, November-April, was 3.7 inches — that for the growing season was 1.6 inches.

Land use changes involving agronomic improvements such as increased levels of fertilization and establishment of meadows of deep-rooted legumes appear to affect the water-flow pattern in a similar manner but considerably less in magnitude. For example on a treated 74.2-acre cropped watershed in which the wheat yields were increased from 10 to 30 bushels per acre, corn from 50 to 100 bushels per acre, and a shallow-rooted meadow at two tons per acre was changed to a deep-rooted meadows at five tons per acre, the annual streamflow in the 19th year was 1.2 inches less than that in the untreated condition. Evaluations of this nature are extremely valuable in developing watershed management programs whether they be for soil stabilization, flood prevention, crop production, or water conservation.

May-September, 1948		Mulch Tillage
Management	Runoff Inches	Tons/acre Erosion
<i>Conventional tillage</i>		
Untreated	2.86	23.0
Treated	1.14	7.8
<i>Mulch Minimum tillage</i>		
Treated	.05	.03

## LAND TREATMENT'S EFFECT ON SOIL LOSS



Conservation practices on a small 3-acre watersheds reduced runoff and soil loss, and increased corn yield

Corn years	Runoff (inches)		Soil loss per acre (tons)		Crop yield per acre (bu.)	
	Untreated	Treated	Untreated	Treated	Untreated	Treated
1942	1.2	1.1	21	5	58	47
1946	2.8	2.2	19	4	52	59
1950	6.7	4.3	29	7	62	86
1954	.1	0	.1	0	60	98
1958	.9	1.0	.1	.2	45	118

The reduction in flood peaks resulting from planting pine tree seedlings on two-thirds of the 43.6-acre watershed has been quite noticeable — for the “average floods.” For the “big storm,” there has not yet, in 20 years, been any measurable reduction in flood peak flow. Either the data are too few for evaluation, the magnitude of flow change too small to show up, or the vegetation has not had time enough to affect the soil conditions necessary to cause a change in flood peaks. It is possible that this type of land treatment alone on this soil may not be an effective measure for reducing the “big flood” — even on a small watershed. Sizable, but erratic, reductions in average peak runoff rates have been noted under conservation crop rotation watersheds of 30 acres or more.

There is evidence that *surface flow* has been greatly reduced by woodland plantings and by conservation treatment of crop and grassland. Substan-

tial reductions were observed in *average* flood peak flows from reforested and ~~framed~~ <sup>conserved</sup> (conservation practices) watersheds of less than three acres in size. Infiltrated storm water, however, often penetrates the soil only a few inches and then flows rapidly over impeding soil layers and through root and animal channels. Much of this water reaches the surface streams during the storm period and contributes to flood runoff even during summer storms when there are large volumes of unused pore space at lower depths.

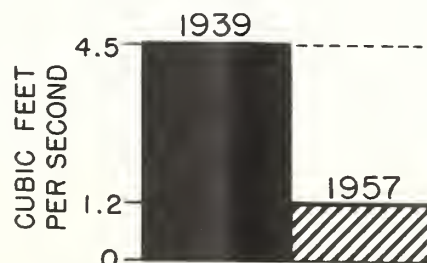
Studies of means to increase and to make greater use of the soil's pore space for quick water absorption are needed. This need applies to crop and pasture lands as well as woodlands.

## WOODLAND PLANTINGS AFFECT FLOOD FLOWS



June 1957

"AVERAGE" FLOOD PEAKS  
ON A 43.6-ACRE WATERSHED

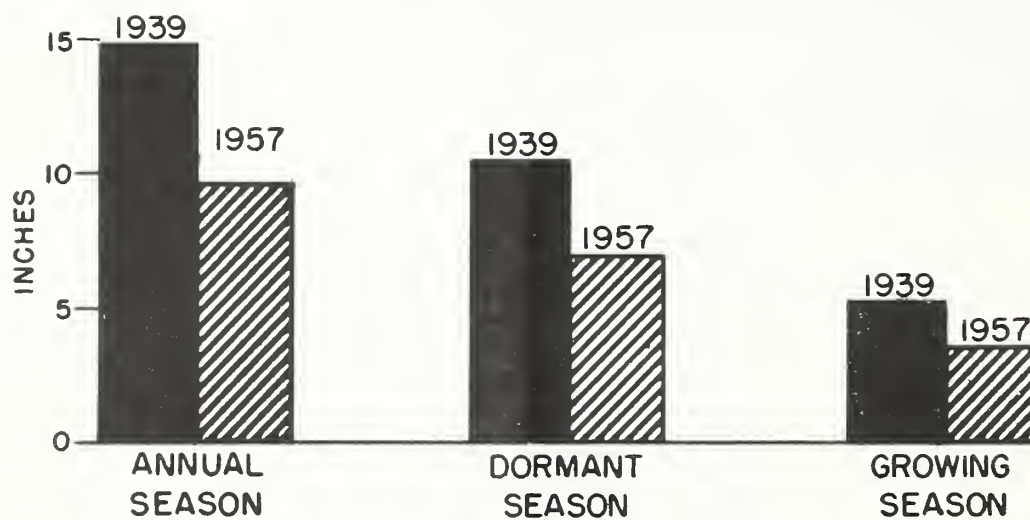




## LAND TREATMENT'S EFFECT ON STREAM FLOW



VOLUME OF STREAM FLOW  
FROM 43.6-ACRE WATERSHED  
(TREES PLANTED IN 1939)





## UNTREATED

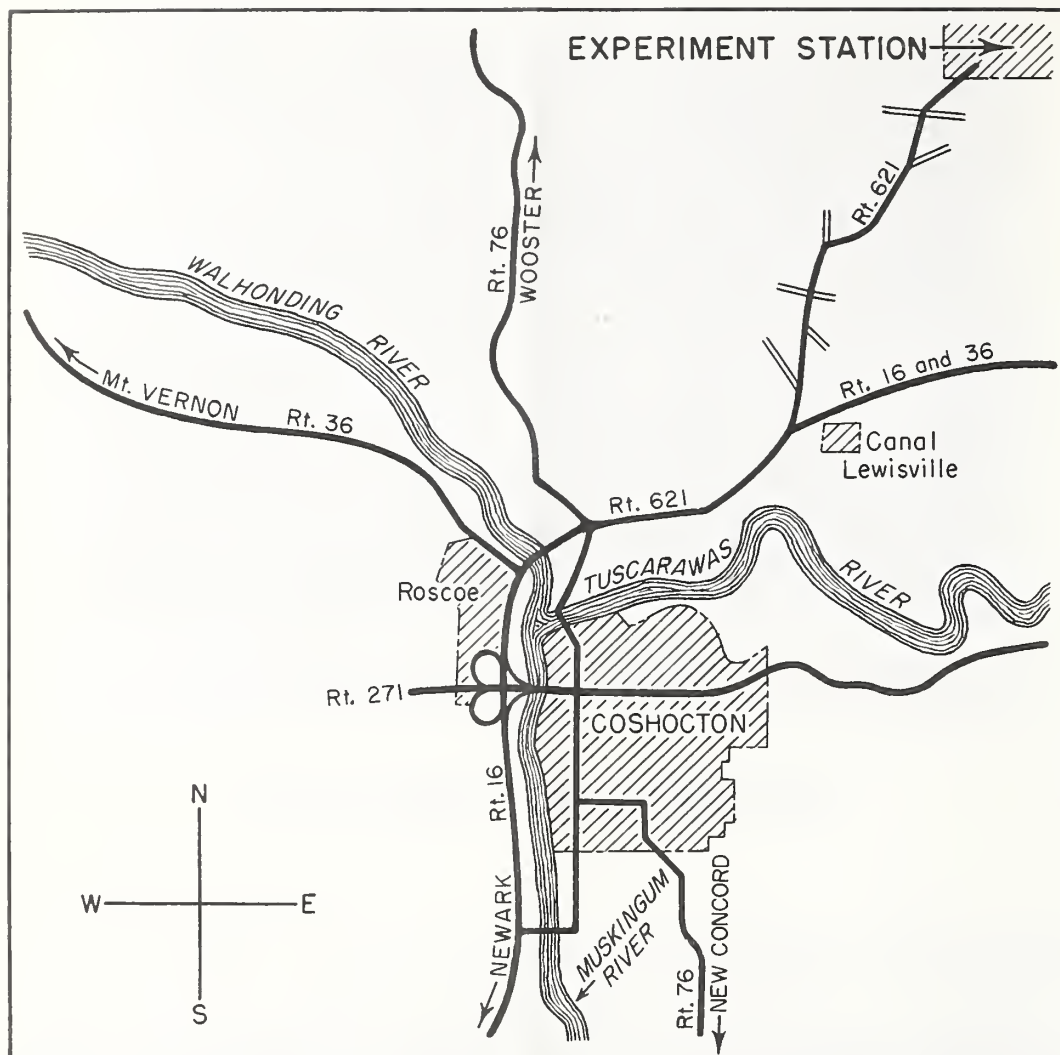


**Sloping row; production of 50 bu. corn, 10 bu. wheat, 2 ton hay per acre**

## CONSERVATION TREATMENT



**Contour tillage; production level of 100 bu. corn, 30 bu. wheat, 5 ton hay per acre**



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